Claims

1. A total-reflection x-ray fluorescence apparatus comprising:

an x-ray source for providing x-rays;

a doubly-curved x-ray optic for diffracting the x-rays;

a surface onto which at least some of the diffracted x-rays are directed; and

an x-ray detector for detecting resultant x-ray fluorescence emitted by any foreign matter present on the surface.

2. An apparatus as recited in claim 1 wherein the doubly-curved x-ray optic also focuses the x-rays on to the surface.

3. An apparatus as recited in claim 1 wherein the doubly-curved optic is a crystal or multi-layer optic.

4. An apparatus as recited in claim 1 wherein the doubly-curved x-ray optic has one or more atomic planes.

5. An apparatus as recited in claim 4 wherein the atomic planes are curved to form a toroidal, ellipsoidal, spherical, parabolic, or hyperbolic shape.

6. An apparatus as recited in claim 1, further comprising one or more apertures for limiting a convergent angle of the diffracted x-rays, wherein the convergent angle comprises the angle subtending the upper and lower extents of the diffracted x-rays.

7. An apparatus as recited in claim 6 wherein the one or more apertures are positioned at at least one of before the x-ray optic and after the x-ray optic.

8. An apparatus as recited in claim 6, wherein the one or more apertures comprise an elongated slot.

9. An apparatus as recited in claim 6, wherein the one or more apertures produce a convergent angle for the diffracted x-rays which is less than the critical angle for the total reflection of the x-rays from the surface for the wavelength of the x-rays.

10. An apparatus as recited in claim 1, wherein the doubly-curved x-ray optic employs Bragg's law in diffracting the x-rays .

11. An apparatus as recited in claim 1, further comprising an analyzer for analyzing the x-ray fluorescence detected by the detector.

12. An apparatus as recited in claim 1, wherein the surface is an optical reflection surface.

13. An apparatus as recited in claim 1, wherein the surface is a surface of a semi-conductor wafer.

14. An apparatus as recited in claim 1, wherein the locations of the doubly-curved x-ray optic, x-ray source, and point of impingement upon the surface define an optical circle of radius R wherein the doubly-curved x-ray optic has an optic surface of radius 2R and one or more atomic planes essentially parallel with the optic surface.

15. An apparatus as in claim 14, wherein the doubly-curved x-ray optic provides one of symmetric or asymmetric Bragg diffraction.

21 16. An apparatus as recited in claim ~~14~~ 19, wherein the atomic planes are curved to form a toroidal, ellipsoidal, spherical, parabolic, or hyperbolic shape.

22 ~~17.~~ 19 An apparatus as in claim ~~14~~, wherein the doubly-curved x-ray optic has a transverse plane perpendicular to the optic circle wherein in the transverse plane the atomic planes are circular.

Pub. 24

18. A method for detecting presence of foreign matter on a surface using a doubly-curved x-ray optic, comprising:

providing a source of x-rays;

diffracting at least some of the x-rays using a doubly-curved x-ray optic and impinging the diffracted x-rays upon the surface;

detecting flourescent x-rays responsive to the impingement from any foreign matter present on the surface.

19. A method as recited in claim 18, wherein the diffracting focuses the at least some x-rays onto the surface.

20. A method as recited in claim ~~18~~, further comprising impinging the diffracted x-rays upon the surface so that the x-rays are totally-reflected from the surface with little or no x-ray scatter.

34 ~~21.~~ 33 A method as recited in claim ~~18~~, further comprising exciting foreign matter present on the surface with the diffracted x-rays so that the foreign matter emits the fluorescent x-rays.

22. A method as recited in claim 18, further comprising passing the x-rays through at least one aperture to limit the convergent angle of the x-rays, wherein the convergent angle comprises the angle subtending the upper and lower extents of the diffracted x-rays.

23. A method as recited in claim 22, wherein the passing through at least one aperture is practiced at at least one of: before the x-ray optic or after the x-ray optic.

24. A method as recited in claim 18, further comprising analyzing the detected x-rays to determine the nature of the foreign matter.

25. An apparatus for diffracting x-rays comprising:

an x-ray source and image defining an optic circle of radius R;

an x-ray optic having a surface and a plurality of atomic planes having a radius R_P which intersect the surface at an angle α;

wherein the radius of the atomic planes R_P is defined by the equation

$$R_P = 2R \cos \alpha.$$

26. An apparatus as recited in claim 25, wherein the angle α is grater than 0° and less than 90°.

27. An apparatus as recited in claim 26, wherein the angle α is greater than 0° and less than 20°.

28. An apparatus as recited in claim 25, wherein the optic is a doubly-curved optic.

29. An apparatus as recited in claim 28, wherein the doubly-curved optic is curved to a toroidal, ellipsoidal, spherical, parabolic, or hyperbolic in shape.

30. An apparatus as recited in claim 28, wherein the doubly-curved optic exhibits asymmetric Bragg diffraction.

31. An apparatus as recited in claim 28, wherein the doubly-curved x-ray optic also focuses the x-rays on to the surface.

32. A total-reflection x-ray fluorescence apparatus comprising:

an x-ray source for providing x-rays;

a doubly-curved x-ray optic for diffracting the x-rays having a surface and a plurality of atomic planes of radius R_P which intersect the surface at an angle α;

a surface onto which at least some of the diffracted x-rays are directed; and

an x-ray detector for detecting resultant x-ray fluorescence emitted by foreign matter present on the surface;

wherein the radius of the atomic planes R_P of the doubly-curved optic is defined by the equation $R_P = 2R \cos \alpha$.

33. An apparatus as recited in claim 32, wherein the angle α is grater than 0° and less than 90°.

34. An apparatus as recited in claim 33, wherein the angle α is greater than 0° and less than 20°.

35. An apparatus as recited in claim 32, wherein the optic is a doubly-curved optic.

36. An apparatus as recited in claim 35, wherein the doubly-curved optic is curved to a toroidal, ellipsoidal, spherical, parabolic, or hyperbolic in shape.

37. An apparatus as recited in claim 32, wherein the doubly-curved optic exhibits asymmetric Bragg diffraction.

38. An apparatus as recited in claim 32, wherein the doubly-curved x-ray optic also focuses the x-rays on to the surface.

39. An apparatus as in claim 2, wherein the doubly-curved x-ray optic focuses to a footprint on the surface, the foot print having a largest dimension less than 1 mm.

40. An apparatus as in claim 39, wherein the doubly-curved x-ray optic focuses to a footprint on the surface, the foot print having a largest dimension less than 500 microns.